

## Loading Configurations and Ground Reaction Forces During Treadmill Running in Weightlessness

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### INTRODUCTION

Studies have shown losses in bone mineral density of 1-2% per month in critical weight bearing areas such as the proximal femur during long-term space flight (Grigoriev, 1998). The astronauts currently onboard the International Space Station (ISS) use a treadmill as an exercise countermeasure to bone loss that occurs as a result of prolonged exposure to weightlessness.

A crewmember exercising on the treadmill is attached by a harness and loading device. Ground reaction forces are obtained through the loading device that pulls the crewmember towards the treadmill surface during locomotion. McCrory et al. (2002) found that the magnitude of the peak ground reaction force (pGRF) during horizontal suspension running, or simulated weightlessness, was directly related to the load applied to the subject. It is thought that strain magnitude and strain rate affects osteogenesis, and is a function of the magnitude and rate of change of the ground reaction force. While it is not known if a minimum stimulus exists for osteogenesis, it has been hypothesized that in order to replicate the bone formation occurring in normal gravity (1G), the exercise in weightlessness should mimic the forces that occur on earth. Specifically, the pGRF obtained in weightlessness should be comparable to that achieved in 1G.

While exercising on the treadmill, the crewmembers currently utilize various

bungee configurations to create specific loads. These configurations are derived from a load prediction table based on weight and leg length measurements during static testing. We do not know how the various configurations affect the pGRF during running onboard the ISS.

Therefore, the purpose of this investigation was to determine the pGRFs that occur during locomotion in weightlessness utilizing the various loading configurations used by crewmembers onboard ISS.

### METHODS

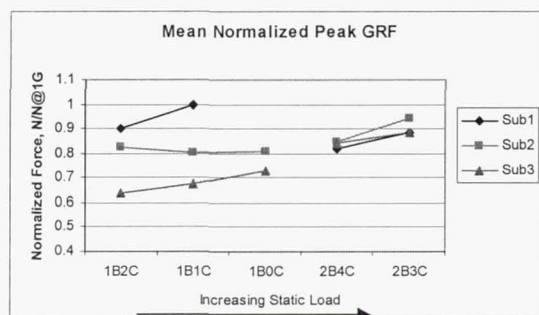
Three subjects ( $172.67 \pm 13.65$  cm;  $76.56 \pm 15.06$  kg) ran at 5 mph (2.24 m/s) during weightlessness onboard the KC-135 aircraft and on the ground (1G). The number of available KC-135 flights limited subject size. The KC-135 flies in a parabolic trajectory allowing for approximately 25 sec of weightlessness. Vertical GRF data were collected during 2 trials at each load with a force treadmill (Kistler Gaitway, Amherst, NY) at 250 Hz for 25 sec. Each loading configuration was tested separately in a predetermined order of 1 bungee - 2 clips (1B2C), 1 bungee - 1 clip (1B1C), 1 bungee - 0 clips (1B0C), 2 bungees - 4 clips (2B4C), and 2 bungees - 3 clips (2B3C). Clips are used to decrease the length of the bungees, reducing the applied load based on the bungee's stiffness. Each arrangement is described as the bungee/clip setup attached to the hip on each side of the harness. One-

bungee configurations used bungee and clips in series, while two-bungee configurations had both bungees in parallel, with the clips in series with the combined pair. One data set (1B1C, Sub 1) was lost due to hardware malfunctions during data collection.

Stride Rate (SR), stride length (SL) and pGRF data were processed using software included with the treadmill. For each trial, the mean of each variable was computed for all recorded footfalls. Any partial footfalls measurements were eliminated from the analysis.

## RESULTS AND DISCUSSION

Comparison of pGRF, SR, and SL between weightlessness and 1G, means were normalized to 1G values (see Figure 1). Estimates of loading levels obtained from static load tests indicate that subjects were loaded at 55-95% BW when using one bungee, and at 95-144% BW when using two bungees.

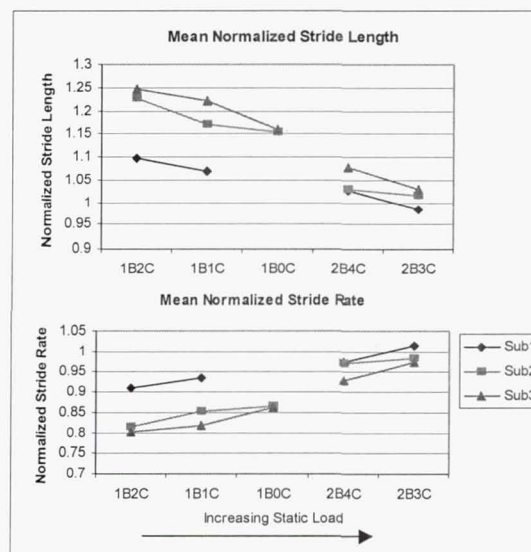


**Figure 1:** Mean Normalized Peak GRF values for each subject, for all bungee/clip configurations and 1G

The normalized force data show that for the two-bungee configurations producing vertical subject loads greater than 1 BW, that pGRF was less than that observed during 1G running.

Examination of mean SR and SL suggest that when loaded with two-bungees, SR

tended to increase and SL tended to decrease with increasing load and approached those typically observed during 1G (see Figure 2). The spread of individual curves suggest that normalized pGRF, SR and SL are less dependent on subject size and weight for the two-bungee configurations than for the one-bungee configurations.



**Figure 2:** Mean Normalized SL and SR for all configurations for each subject.

## SUMMARY

Our findings suggest that for the loading configurations studied, even though SL and SR may replicate that measured during 1G, pGRF is less than that produced in 1G. This occurs even when predicted loads are greater than 1BW. Variations are greater in pGRF, SR and SL between subjects during one-bungee running than during two-bungee running, suggesting that subject mass and height may affect pGRF, SR and SL when using one bungee configurations.

## REFERENCES

- McCrory, J.L. et al. (2002). *Aviat Space Environ Med*, **73**(7),625-631.
- Grigoriev, A.I. et al. (1998). *Aviaksom Ekolog Med*, **32**(1),21-25.